Seafloor Sediment
Environmental Measurements In Support Of
High Frequency Sound Interaction In Ocean Sediments

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LONG-TERM GOALS

The project is directed toward the quantification of selected sediment properties crucial to the modeling of high frequency sound interaction in ocean sediments. The effort is two-fold. One part of the research is to introduce a novel instrument and approach to making *in situ* three-dimensional measurements of sediment permeability. The second part of the research is to perform a study of the sediment microfabric that will lead to a better understanding of the sediment pore fluid pathways and porometry. The long-term goal is the development of microfabric models that describe important sediment properties such as fluid flow characteristics, isotropy and anisotropy, stress-strain behavior, and 3-D space pore geometry where water, gas, and biogenic materials are found (Bennett *et al.* 1989, 1996, 1999 a and b).

SCIENTIFIC OBJECTIVES

Scientific and technical objectives of the project are:
(1) to develop and test an *in situ* permeameter to be deployed in the full scale DRI field experiment in October 1999 and
(2) to study selected sediment samples for quantitative microfabric analysis.

In conjunction with (1), an additional important objective is to conduct permeability tests using a sand probe tripod and *in situ* permeability probe in cooperation with Dr. Paul Johnson (University of Washington). Dr. Johnson will collect *in situ* wet bulk density/porosity and acoustic data with the UW probe. These measurements will provide a strong statistical database of *in situ* sediment properties crucial to high frequency modeling.

Concurrently with (2), efforts to develop techniques for "undisturbed" sediment sampling of sandy

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deposits and laboratory processing of these samples for electron microscopy has pushed forward. The samples obtained will be used for the study, reconstruction, and quantification of the two and three-dimensional microfabric and porometry (Bennett *et al.*, 1989). Interstitial organic material will be preserved during sampling which will lead to a better understanding of the interrelationships between the solids (mineral grains) and the microbiota and/or organic debris in the sediment pores (Baerwald et al. 1991, Bennett et al. 1999a).

APPROACH

The design and development of the latest version of the permeameter probe was founded heavily on proven aspects of designs of earlier *in situ* probes (Bennett *et al.*1990, 1989). State-of-the-art techniques used by other researcher and engineers were incorporated into the design as required and include sensor technology, materials, electronics, and computer technology. The permeameter probe was designed and built by SEAPROBE, Inc. with modeling assistance by Research Dynamics. The University of Washington (FY-99) designed the data acquisition system and, with assistance from SEAPROBE, conducted laboratory tests.

The microfabric studies comprise refinements and extensions of presently prevalent scientific techniques as well as incorporation of input from the new capabilities introduced with the newer instrumentation. Originally employed in the study of fine-grained sediments, microfabric analyses of sand, for example, represents an effort to collect "undisturbed" samples that preserve *in situ* structure and organic materials and, from study of these samples, reconstruct and model the two and three-dimensional fabric and pore fluid pathways of the sediments. The development of new methods and techniques, laboratory analyses, and digital image analysis has been a major aspect of the research in FY-99. The microfabric laboratory research is carried out at the Biology Department, University of Southern Mississippi, Hattiesburg, MS. Research Dynamics has contributed to the permeameter modeling effort and is assisting in the microfabric modeling. R. Bennett (SEAPROBE, Inc.) is coordinating the above-described research.

WORK COMPLETED

In Situ Permeameter

FY-99 included meeting attendance, planning, and coordination of efforts with other DRI-SAX researchers, especially Dr. Paul Johnson of the University of Washington. In FY-99 the permeameter was designed and built by SEAPROBE, Inc., and a report was prepared for Dr. Paul Johnson and Dr. Joseph Kravitz (Bennett and Hulbert, 1998). The report included not only the mechanical design of the probe but also the modeling of the flow rates, pore pressure fields, and pressure responses predicted to be encountered during its application in the field that led to its final design. Flow rates and pressure response limits were estimated. Pore pressure fields to be developed during over-pressuring of the *in situ* sediment during flow tests were modeled and calculated. Estimates were made of the forces required to penetrate the sandy sediments (a range of expected wet bulk densities and porosities) to be tested. The report also gave estimates of the effective stress that must be considered when over-pressuring the sediment during field tests.

Detailed mechanical drawings of the permeameter were prepared and delivered to the machine shop for building of all the required components. The development of the experimental design for laboratory work, probe testing, and calibration was periodically discussed in detail with Dr. Paul

Johnson. Throughout the year, numerous technical meetings were held to review and discuss technical details, progress, and plans of not only the permeameter design and fabrication but also the microfabric research.

Microfabric

The major accomplishments were:
(1) acquired software for 2-D and 3-D reconstruction of sediment microfabric;
(2) acquired hardware to remove reproducible amounts (slices) from the sample and polish the surfaces of embedded sediment; and
(3) acquired actual samples of sediments as part of a test run in preparation for the collection of sediments scheduled for, October 1999 Field exercise.

Software for 2-D and 3-D reconstruction of sediment. The Bioquant software package was purchased from R & M Biometrics. This powerful software package is used to process images and import photographs of sediment surfaces prepared as described in 2) above. We have acquired the associated microscope lenses and lighting system necessary to take clear photographs of the samples. We are examining several appropriate video cameras to choose the most appropriate for this study.

Hardware for polishing samples. A polisher and a grinding wheel was purchased that will allow us to polish (remove) micron amounts of material reproducibly. Associated with this equipment, we had 15 mm coring devices made to subsample the sediment cores, and we have worked out the details of collecting the sediment with minimal disturbance. The optimal diameter and the optimal length of each sample (no more than 1 cm) was determined empirically with respect to the polishing/grinding equipment.

Acquisition of sediment samples. During the June DRI field exercise, we collected, processed, and embedded 80 subsamples taken from seven cores collected at three sampling sites. Processing the samples involves grinding a smooth surface on the sample; capturing a video image of the surface and importing it into the Bioquant software; polishing off a small, known amount of surface; capturing and importing another image; and repeating this process until a number of surfaces sufficient to describe that portion of the sample volumetrically and quantitatively have been photographed. Initial analysis will involve estimates of sand grain size and pore size. Three-dimensional reconstruction of sediment samples will follow.

The next steps in this project involve perfecting the precision with which we can polish samples, learning how to automate to the extent possible the image capture and software analysis of the sample surfaces to maximize the number of samples that can be processed, and working with various quantitative techniques for expressing the microfabric and porometry of the marine sediment. In parallel with this, we will begin analysis of marine sediment for microbial presence. This will involve examination at a different scale than required for fabric analysis of the sand. Scanning electron microscopy has already proven valuable to our preliminary studies and will be used more extensively for the microfaunal aspects and fine-grained matrix characterization of this study.

RESULTS

- Developed and tested embedding and sample surface preparation techniques for sands for optical

and EM studies.
- Obtained and tested precision grinding and surfacing apparatus.
- Evaluated software for digital image analysis and reconstruction of the two and three-dimensional microfabric of sands.
- Designed and built mini-permeameter for use with the UW sand probe.
- Developed and modeled permeameter pore pressure behavior and zone of over-pressuring during flow tests.
- Completed several reports and publications (see references).

IMPACT/APPLICATIONS

Acoustic behavior in sediment is complex, and reliable predictive capabilities (models, numerical formulations, and quantitative estimates) must consider the combined effects of the sediment properties at various scales depending upon the frequency of interest. Databases of *in situ* sediment property data presently available fall short of those necessary for the testing and evaluation of high frequency sound interaction models for shallow water coastal sediment types. These studies will provide important input parameters for sediment in coastal areas having direct impact on U.S. Naval activities. These studies have application to environmental management activities, understanding of hydrologic processes, and engineering and acoustic problems involving objects placed on and in the seafloor.

TRANSITIONS

The project is providing important environmental data on the sediment physical properties and variability and the microscope characteristics of sandy sedimentary deposit. These data are important to applied problems of interest to the Navy in areas of mine burial, buried mine performance, detection, and environmental assessment.

RELATED PROJECTS (Not Applicable)

REFERENCES

1) Bennett, R.H., K.M. Fischer, D.L. Lavoie, W.R. Bryant and R. Rezak, 1989. Porometry and Fabric of Marine Clay and Carbonate Sediments: Determinants of Permeability. Marine Geology, Vol. 89, pp. 127-152.

2) Bennett, R.H., H. Li, J.T. Burns, C.M. Percival and J. Lipkin, 1989. Application of Piezometer Probes to Determine Engineering Properties and Geological Processes in Marine Sediments. Applied Clay Science, Vol. 4, pp. 337-355.

3) Bennett, R.H., H. Li, D.N. Lambert, K.M. Fischer, D.J. Walter, C.E. Kickox, M.H. Hulbert, T. Yamamoto and M. Badiey, 1990. In Situ Porosity and Permeability of Selected Carbonate Sediment: Great Bahama Bank Part I: Measurements. Marine Geotechnology, Vol. 9, pp. 1-28.

4) Bennett, R.H., J.T. Burns, H. Li, D. Walter, P.J. Valent, C.M. Percival and J. Lipkin, 1990. Subseabed Disposal Project Experiment: Piezometer Probe Measurement Technology. Geotechnical Engineering of Ocean Waste Disposal, ASTM STP 1087, Kenneth R. Demars and Ronald C. Chaney (Eds.), American Society for Testing and Materials, Philadelphia, pp.175-189.

5) Baerwald, R.J., P.J. Burkett and R.H. Bennett, 1991. Techniques for the Preparation of Submarine Sediments for Electron Microscopy. Chapter 35, pp. 309-320, in: Microstructure of Fine-Grained Sediments: From Mud to Shale, Springer-Verlag, 582p.

6) Bennett, R.H., M.H. Hulbert, M.M. Meyer, D.M. Lavoie, K.B. Briggs, D.L. Lavoie, R.J. Baerwald and W.A. Chiou, 1996. Fundamental Response of Pore-Water Pressure to Microfabric and Permeability Characteristics: Eckernförde Bay. Geo-Marine Letters, Vol. 16, pp.182-188.

7) Bennett, R.H., B. Ransom, M. Kastner, R.J. Baerwald, M.H. Hulbert, W.B. Sawyer, H. Olsen and M.W. Lambert, 1999. Early Diagenesis: Impact of Organic Matter on Mass Physical Properties and Processes, California Continental Margin. Marine Geology, Vol. 159, pp.1-34.

REPORTS/PAPERS RELATED TO THE DRI-SAX PROGRAM

8) Bennett, R.H. and M.H. Hulbert, 1998. In Situ Mini-Permeameter Probe Design Considerations. SEAPROBE, Inc. Technical Report No. SI-0098-04, 51p., (Not for general distribution).

9) Bennett, R.H., 1999. Panama City Coastal Sands DRI Sites 10 and GS-172 Sediment Analyses Informal Data Report. SEAPROBE Technical Report No. SI-0099-03, 26p.

10) Bennett, R.H., H.W. Olsen, M.H. Hulbert, R.J. Baerwald, W.B. Sawyer and B. Ransom, 1999. Organic Matter and Geotechnical Properties Interrelationships: Marine Sediments. In the Proceedings of the 13th ASCE Engineering Mechanics Division Specialty Conference, Johns Hopkins University, Baltimore, June 13-16, (CD-ROM).